Chapter 3. Project Alternative Evaluation

As part of its Phase II evaluation, CALFED compiled a list of 52 potential surface storage project alternatives and associated engineering, cost estimate, and environmental information. An interagency team of specialists reviewed available data and screened out clearly impracticable alternatives. This initial screening was based on minimum storage capacity and potential for conflict with CALFED's restoration programs, solution principles, and policies. New onstream projects were excluded because of their greater potential for negative environmental impacts. During the initial screening, CALFED narrowed the number of potential sites for future consideration to twelve. Four of these are offstream storage projects located north of the Delta, namely Sites, Colusa, Thomes-Newville, and Red Bank. This chapter describes in detail each of these project alternatives and summarizes the evaluations conducted to date.

Evaluation of north of the Delta offstream storage alternatives is continuing. Information gathered during this investigation will be used for the second stage screening as well as for environmental documentation, permits, and project feasibility evaluations. The second stage screening will lead to selection of a preferred alternative for the North of the Delta Offstream Storage Investigation. In addition, information developed will be used in CALFED's Water Management Strategy Evaluation Framework. This long-term decision-making framework will allow comprehensive comparisons of surface storage projects with other strategies included in CALFED's initial list, including water use efficiency, recycling, and water transfers.

Alternative Projects Description

The four north of the Delta offstream projects provide a range of potential water supply reliability benefits, but would serve similar project purposes. Since all of the projects are upstream of the Delta and adjacent to the Sacramento River, the kinds of benefits, such as supplemental yield for various uses and reduced diversions from the Sacramento River during the peak local delivery period will vary primarily in scale. Comparative project statistics are shown on Table 3-1. All of these projects have been investigated to varying degrees in the past. Current studies have updated and augmented these past studies as needed to allow comparative evaluation of alternatives. Each of these projects is described individually in more detail below.

Sites Project

Consideration of major offstream storage at Sites was first documented in a December 1964 U.S. Bureau of Reclamation report titled *West Sacramento Canal Unit*. This study evaluated a planned extension of the Tehama-Colusa Canal south into Solano County and included a 1.2 maf Sites Reservoir as part of that plan. The potential to use Sites as a stand-alone project to help serve statewide multiple water needs was not considered until this current evaluation. The larger 1.8 maf Sites Reservoir was not considered by either DWR or USBR until the mid-1970s and was sized at the maximum elevation considered practicable at this location.

Table 3-1. Comparative Project Statistics for the Sites, Colusa, Thomes-Newville, and Red Bank Projects

Project Feature	Sites	Colusa	Small Thomes-Newville	Large Thomes-Newville	Red Bank	
					Dippingvat	Schoenfield
Storage (acre-feet)						
Gross	1,800,000	3,000,000	1,900,000	3,000,000	104,000	250,000
Dead	40,000	100,000	50,000	50,000		
Drainage Area (square miles)	85	115	63	63	132	39
Reservoir Surface Area (acres)	14,000	28,000	14,500	17,000	1,270	2,770
Dam Height/Volume (feet/1,000yd^3)						
Sites	290/3,800	290/3,800	325/16,000	400/33,000	250/367	300/467
Golden Gate	310/10,600	310/10,600	75/600	150/2,000	75/19	
Prohibition		230/11,300			115/55	
Owens		260/11,700				
Hunters		260/24,700				
Logan		270/30,600				
Newville						
Burrows Gap (largest saddle)						
Schoenfield (RCC)						
Dippingvat (RCC)						
Lanyan (RCC)						
Bluedoor (RCC)						
Saddle Dams (Number/Height)	9/130	7/140	None	4/75		4/85
Reservoir Elevation (feet)						
Normal	520	520	905	980	1,205	1,017
Minimum	320	320	685	685	1,103	830
Average Annual Natural Reservoir Inflow (acre-feet)	15,000	20,000	20,000	20,000	96,400	16,000
Reservoir Evaporation						
Average Annual	40,000	80,000	50,000	60,000		
Critical Period Total	220,000	440,000	300,000	360,000		
Pumping						
Static Lift from T-C Canal (feet)	320	320	655	730		
Maximum	120	120	435	435		
Minimum	5 - 8	5 - 8	2	2 - 5		
Capacity (1,000 ft^3/s)						

For Golden Gate Dam, statistics shown are for the downstream curved embankment alternative.

The Sites Project site is located about 8 miles west of Maxwell in Antelope Valley, which is drained by Stone Corral and Funks Creeks. The drainage area of these watersheds totals 85 square miles. Two sizes of reservoir were investigated in the past—1.2 maf at 480-foot normal water surface elevation and 1.8 maf at 520-foot normal water surface elevation. However, due to its greater water supply yield, Large Sites appears the more favorable project. Therefore, this investigation to date has focused mainly on Large Sites Reservoir and hereafter will be referred to simply as Sites Reservoir. Two main dams—Golden Gate on Funks Creek and Sites on Stone Corral Creek—and nine saddle dams along the northern edge of the project are required to form the reservoir. Sites Reservoir would occupy a maximum area of 14,000 acres.

Sites Reservoir would be formed by a 290-foot-high Sites Dam on Stone Corral Creek and a 300 or 310-foot-high Golden Gate Dam on Funks Creek. Nine saddle dams ranging up to 130-feet-high would also be built along the reservoir's northern boundary to prevent water from spilling over the ridge into Hunters Creek. Presently, 40-foot-high Funks Dam forms a 2,000 acre-foot reservoir 1 mile downstream of the Golden Gate Dam site. This reservoir was constructed by USBR and is part of the Tehama-Colusa Canal System. Funks serves as a surge reservoir to stabilize flows down the canal as diverters come on- and off-line. Either the existing or an enlarged Funks Reservoir would serve as a forebay/afterbay to the Sites or Colusa Project.

For most of the water source options, imported water entering Sites or Colusa Reservoir would pass through Funks Reservoir. More specifically, it is the terminal location for all of the optional water conveyance routes to these reservoirs derived from sources east of the proposed reservoirs. The exception is a potential water supply source developed from the upper Stony Creek watershed, west of Sites, by diverting water from existing reservoirs through a tunnel and conveying it by gravity via canals, tunnels, and streams directly into the reservoir. These upper Stony Creek water supply source and conveyance options are the only ones that do not convey water through Funks and then require a lift into Sites Reservoir. However, all water source options would flow through Funks Reservoir when water is released to meet downstream water demands.

If daily pumpback operations were incorporated into either project, then Funks Reservoir would probably need to be enlarged to around 8,000 af. A pumpback or pumped-storage operation would maximize power production by releasing water through hydroelectric generation facilities in excess of downstream requirements and then returning it to storage in the offstream reservoir during off-peak periods. This water is then available again for release and generation during peak power demand periods. This type of operation scenario will be evaluated further as the study progresses.

The Sites or Colusa Project water control features (appurtenances) include water intake and outlet structures, a pumping and generating plant, and emergency spillway located at the Golden Gate Dam site on Funks Creek. Sites Dam will have a low-level outlet structure to release stream maintenance flows into Stone Corral Creek.

The proposed operation of the Sites or Colusa Projects would be similar. Each of the water supply source and conveyance alternatives for Sites or Colusa includes water from the Sacramento River through existing, expanded, or new conveyance facilities. Water would be diverted to the offstream reservoir from the Sacramento River and possibly some tributaries, mainly in winter months. During the irrigation season, releases from the offstream reservoir would be made back to local irrigation canals to provide irrigation water in exchange for water that would otherwise have been released from Shasta and diverted downstream from the Sacramento River. The exchanged water would then remain in Shasta Lake for release later in the summer, partially to help cool the upper river for fishery maintenance purposes, and to be used downstream for agricultural, environmental, and urban purposes.

Development of a Sites or Colusa Project with diversion from the Sacramento River will either require modification of the Tehama-Colusa and/or Glenn-Colusa Canal intakes or construction of a new intake for new conveyance. These modified or new facilities will allow large-scale winter diversions of water from the river without adversely affecting the river fishery or other biologic resources. Total diversion capacity from the Sacramento River for the currently proposed source and conveyance alternatives does not exceed 5,000 cfs. A new canal diverting 5,000 cfs from the Sacramento River, east of Maxwell, is also being considered. Colusa Basin Drain floodflows could also be diverted to this new canal for conveyance to offstream storage. High winter flows diverted into these canals would be conveyed to Funks Reservoir and then pumped into Sites or Colusa Reservoirs. Other alternative locations and sources of water supply are being evaluated and will be discussed in greater detail later in this chapter.

When water is released from the reservoir, it would be routed through generators to generate power, which could help offset the power and costs associated with pumping. The economic value of power used to supply the reservoirs will be largely offset by the value of power generated, even though consumption would exceed generation. This is due to the project's ability to pump during periods of lower power costs and generate during periods of higher power costs.

Hydrology of Optional Water Supplies

Project formulation for the alternative offstream projects includes identification of water supply sources that will be diverted to storage. A list of optional water supply sources and conveyance has been developed and evaluation has been initiated to determine preferred sources for each project. The Red Bank Project has only one water supply source under consideration. The project formulation decisions have not yet been made and will require environmental, engineering, and economic evaluation of the water supply source options. The following discussion reflects the evaluation of the water supply sources to date.

Flows of various nearby streams were evaluated to determine the quantity of water that could be diverted to storage in the four alternative offstream reservoirs. In general, three steps were required in determining the hydrologic and water supply characteristics of the optional water supply sources. First, historical flows of the streams were reviewed to provide a preliminary assessment of the relative scale of available water in a given stream.

Second, the historical flows were subjected to local and downstream operational constraints to determine the divertible flow. Local operational constraints include instream flow requirements of the source stream, limitations related to the operations and water rights of existing local water supply projects, and existing or proposed diversion and conveyance facility capacities. Downstream operational constraints include lower Sacramento River flow requirements and requirements in the Sacramento–San Joaquin Delta.

Third, divertible flows of optional sources are combined to determine the water supply yield associated with alternative water supply projects by using a reservoir simulation (CALSIM) model. In this step, water supplies are subject to the offstream reservoir capacity and the system-wide operational constraints of the Central Valley Project and State Water Project. System-wide operational constraints include pumping limitations in the Delta, availability of other system-wide water supplies, and customer demands.

Optional Water Supply Sources

Table 3-2 shows the optional water supply sources considered for the alternative north of the Delta offstream storage projects. Sites, Colusa, and Thomes-Newville Projects each have a number of optional water supply sources. These sources may be packaged in various combinations to generate sufficient water supply for a specific project. The Red Bank Project is unique because there is only one major water supply source being considered for diversion and storage. The six optional sources are the same for Sites and Colusa. Thomes-Newville has three optional water supply sources. Local inflow sources are not shown, but each offstream project would receive some local inflow from the relatively smaller streams that flow directly to the offstream reservoirs.

Table 3-2. Optional Water Supply Sources for North of the Delta Offstream Projects

Sites / Colusa	Thomes-Newville	Red Bank
Colusa Basin Drain	Sacramento River	South Fork Cottonwood Creek
Grindstone Creek	Stony Creek	
Little Stony Creek	Thomes Creek	
Sacramento River		
Stony Creek		
Thomes Creek		

The optional water supply source streams evaluated for north of the Delta offstream storage are the Sacramento River, Stony Creek, Colusa Basin Drain, Thomes Creek, Grindstone Creek, Little Stony Creek, and South Fork Cottonwood Creek. Streamflow records were reviewed to determine the relative quantity of water that has historically flowed in various streams. Table 3-3 shows November through March streamflow volumes at representative locations for the period 1945-1994. The November through March period was chosen to avoid any operational conflicts with existing facilities and water rights. Local irrigation operations often begin in April and conveyance facilities are being used for deliveries. Most of the data shown are directly from gage station streamflow records. A number of the data records needed to be extended or adapted using basic hydrologic correlations. Correlations for the entire period of record were required for Grindstone Creek, inflow to East Park Reservoir, and South Fork Cottonwood Creek.

The Sacramento River is by far the largest water supply source of the options considered. With an average historical five-month flow volume at Butte City of almost 5.5 maf, the river's flow is over 23 times the size of the second largest option, Stony Creek. The three smallest optional water supply sources are Grindstone Creek, East Park Reservoir, and South Fork Cottonwood Creek, each with an average November through March runoff of less than 100 taf. The sources are not independent options. All of the tributary streams contribute to the flow of the Sacramento River. Outflow from East Park Reservoir becomes inflow to Stony Gorge and then ultimately contributes to the flow below Black Butte.

Table 3-3. November - March Streamflow Volumes, 1945-1994 of Optional Water Supply Source Streams

Source and Location	Minimum (taf)	Maximum (taf)	Average (taf)
Sacramento River at Butte City	1,613.4	14,414.6	5,460.7
Stony Creek below Black Butte Dam	1.0	1051.8	234.5
Colusa Basin Drain at Highway 20	38.8	759.2	208.9
Inflow to Stony Gorge Res.	3.6	508.6	151.3
Thomes Creek at Paskenta	7.3	359.1	150.9
Inflow to proposed Grindstone Res.	0.9	301.1	85.4
Inflow to East Park Res. w/ Rainbow Diversion	1.1	221.8	76.2
South Fork Cottonwood Creek at Dippingvat	4.8	259.3	75.4

Streamflow volumes are dependent upon diversion location. In general, volumes increase in the downstream direction. Optional diversion locations for the Sacramento River are at the existing Tehama-Colusa Canal diversion in Red Bluff, the existing Glenn-Colusa Irrigation District Canal diversion in Hamilton City, a new diversion at Chico Landing, and a new diversion opposite Moulton Weir. Diversion locations investigated for Stony Creek include Black Butte Lake, Stony Gorge Reservoir, East Park Reservoir with additional water from the Rainbow Diversion, and at the GCID Canal crossing. The diversion location investigated for Colusa Basin Drain is due west of Moulton Weir, almost 10 miles north of Highway 20. Thomes Creek diversion locations include a number of options west of Paskenta and at the Tehama-Colusa Canal crossing. The Grindstone Creek diversion location is from a potential Grindstone Reservoir. The Grindstone Dam site is approximately 2-1/2 miles upstream from the confluence with Stony Creek. The diversion location for South Fork Cottonwood Creek is at the proposed Dippingvat Reservoir.

Divertible Flow of Water Supply Sources

Divertible flow is computed by imposing local and downstream restrictions on the streamflow volume, including applicable instream flow requirements of tributary streams and the Sacramento River. Divertible flow is also limited by diversion and conveyance capacity of new or existing facilities. A representative divertible flow is shown in Table 3-4 for each of the water supply sources for comparison. The divertible flow value is used as input for the CALSIM operations model.

Table 3-4. November-March Average Divertible Flow

Stream and Location	Conveyance Capacity (cfs)	Divertible Flow (taf)
Sacramento River at Butte City	5,000	587.3
Stony Creek below Black Butte Dam	1,700	234.5
Colusa Basin Drain	3,000	136.5
Stony Gorge Reservoir	1,500	70.2
Thomes Creek	2,100	108.9
Grindstone Reservoir	750	67.9
East Park Reservoir w/ 300 cfs Rainbow Diversion	1,200	30.1
South Fork Cottonwood Creek at Dippingvat	800	52.9

Stony Creek Hydrology and Water Supply

Subsequent to the initial evaluations of optional water supply sources, members of the Technical Advisory Group requested that DWR refine its treatment of options from the upper watershed of Stony Creek. Based on input from TAG members and local project operators, some adjustments were made to the assumptions related to these optional sources. These adjustments did generate corresponding changes in available streamflow volume and the water supply characteristics of these sources. Following is a more comprehensive description of the Stony Creek options.

Stony Creek is a potential source of water supply for an offstream storage reservoir along the western edge of the Sacramento Valley. More specifically, water from Stony Creek could be conveyed to Sites, Colusa, or Thomes-Newville project alternatives for storage. Stony Creek diversion and conveyance options that take advantage of existing reservoirs or conveyance facilities were evaluated for this study.

The major surface water projects in the Stony Creek basin include the Orland Project and Black Butte Dam and Lake. The Orland Project is one of the oldest reclamation projects in the country and includes two main dams and reservoirs, East Park and Stony Gorge. The project is locally operated by the Orland Unit Water Users' Association and provides irrigation water for up to 20,000 acres near Orland, as well as residential, commercial and industrial water supply to about 2,500 residents. East Park Dam and Reservoir are located on Little Stony Creek, about 33 miles southwest of Orland. The capacity of East Park Reservoir is about 51,000 af. In addition to the inflow from Little Stony Creek, East Park receives water from Rainbow Diversion Dam on the mainstem. The Rainbow Feeder Canal is about 7 miles long with a design capacity of 300 cfs. Stony Gorge Dam and Reservoir are located about 18 miles downstream of East Park at the confluence of Little Stony and Stony Creeks. The capacity of Stony Gorge Reservoir is about 50,000 af.

The U.S. Army Corps of Engineers developed Black Butte Dam and Lake, approximately 22 miles downstream of Stony Gorge and 9 miles west of Orland, primarily for flood control in the early 1960s. Black Butte is operated in coordination with a number of other agencies including the OUWUA and USBR for water supply. In addition, the City of Santa Clara generates hydroelectric power. The lake's capacity is about 143,000 af.

Stony Creek Water Supply Source Options

A number of options have been considered for diverting Stony Creek winter flows to offstream storage including:

- Diversion from Black Butte Reservoir to Newville Reservoir;
- Diversion from lower Stony Creek into existing Tehama-Colusa and GCID canals for conveyance to Sites or Colusa Reservoirs;
- Diversion from East Park Reservoir to Sites or Colusa Reservoirs;
- Diversion from Stony Gorge Reservoir to Sites or Colusa Reservoirs; and
- Diversion from proposed Grindstone Reservoir to Stony Gorge Reservoir and rediversion to Sites or Colusa Reservoirs.

The Grindstone Reservoir water supply source option was evaluated at a cursory level. Ranges of reservoir and diversion capacities were considered. The cursory analysis of Grindstone Reservoir indicated a number of undesirable characteristics related to this option including susceptibility to large landslides, relatively large embankment quantities for the dam and saddles, relatively high sediment load in the creek, and close proximity to a fault. While these characteristics would not make the Grindstone Reservoir option technically infeasible, a number of other options appear to be more feasible at this stage of evaluation. Therefore, Grindstone Reservoir as an optional source has been set aside.

The following analysis has focused on the reservoir diversions to Sites or Colusa Reservoirs. Simplified operation simulations using the historic hydrology and current reservoir operations have been used to estimate potential water supply diversions from East Park and Stony Gorge Reservoirs. Potential water supply diversions are simply the amount of water that can be diverted from a source with given conveyance capacities, instream flow, and other operational requirements. Unimpaired inflow to Stony Gorge Reservoir was determined based on historic outflow and changes in storage in East Park and Stony Gorge. Inflow to East Park and Rainbow were estimated as a percentage of the unimpaired Stony Gorge inflow. The area of the watersheds above Stony Gorge, East Park, and Rainbow diversions was determined. Area/precipitation factors of 45 and 31 percent were used for Rainbow and East Park respectively. This means that 45 percent of the unimpaired inflow to Stony Gorge flows past the Rainbow location and 31 percent flows into East Park.

A review of available data and discussions with local project operators provided helpful information. For example, a review of monthly reservoir storage indicates that a significant shift in Orland Project reservoir operations occurred subsequent to construction of Black Butte Reservoir in 1963. After Black Butte Reservoir was built, water in storage at the end of the irrigation season in the Orland Project reservoirs increased an average of about 16,000 af. Local project operators helped refine current project operating criteria, including estimates of instream water releases below the dams.

Criteria were established to determine the potential water supply diversions from Orland Project reservoirs including:

- Instream flow requirements for the creeks below East Park, Stony Gorge, and Black Butte were set at 10, 10, and 30 cfs, respectively. These are based on operator's estimates of current operating practices.
- Diversion is limited to the November through April period to avoid potential impacts to existing projects. This diversion period is one month longer than for other options, but will not conflict with the rights of existing water users.
- Diversion is limited such that end of the month reservoir storage during the diversion period was equal to or greater than historic levels in all three reservoirs.
- A minimum diversion storage level of 20,000 af in East Park and Stony Gorge was established to provide adequate tunnel submersion.

A range of conveyance capacities to the offstream storage alternatives was evaluated to determine optimal sizing of diversion and conveyance facilities. For Stony Gorge, conveyance of 500, 1,000, 1,500, and 2,000 cfs were considered; for East Park, conveyance of 800, 1,000, and 1,200 cfs; the Rainbow Feeder Canal to East Park was sized at 300, 500, 750, and 1,000 cfs.

Potential water supply diversions were analyzed for the above range of facilities for the 1964 through 1994 period. This period was chosen based on the previously mentioned effect of Black Butte operations and the data requirements of CALSIM, the statewide operation simulation model. The potential water supply diversion data was then extended to the standard CALSIM period, 1922 through 1994, by correlation with the Sacramento River Index. Annual potential water supply diversions from Stony Creek sources are shown in Table 3-5 for the 1922-1994 period.

Table 3-5. Stony Creek Reservoir Options Average Potential Water Supply Diversions (taf)

Diversion and Conveyance(cfs)	Existing or Rainbow (300)	Rainbow (500)	Rainbow (750)	Rainbow (1,000)
Stony Gorge (500)	60			
Stony Gorge (1,000)	90			
Stony Gorge (1,500)	107			
Stony Gorge (2,000)	117			
East Park (800)	60	66	68	69
East Park (1,000)	62	70	74	76
East Park (1,200)	63	71	77	80

Water Supply Contribution

Water supply contribution (Table 3-6) is the amount of water actually diverted in an operation simulation to an offstream reservoir from a specific source and is an output from CALSIM. Water supply contribution to an offstream reservoir is dependent on potential water supply diversions and a number of other hydrologic and operational variables that are input to the

CALSIM model. These variables include capacity of the offstream reservoir, water supply diversions from other sources, instream flow requirements, Delta conditions, demands, and Delta diversion facilities.

Table 3-6. Water Supply Contribution (taf) From Sources to 1.8 maf Sites Reservoir (Typical operational studies)

Conveyance Package	Stony Creek	Sacramento River	Colusa Basin Drain	Total
2,000 cfs tunnel from Stony Gorge	117			117
2,100 cfs T-C canal 1,800 cfs GCID canal		143 159		302
2,100 cfs T-C canal 1,800 cfs GCID canal 2,000 cfs tunnel from SG	58	127 141		325
2,100 cfs T-C canal 1,800 cfs GCID canal 3,000 cfs canal from CBD		85 168	63	317

Yield is difficult to assign to a specific source for a project with multiple sources of water. The portion of total water supply contribution from a specific source is an indicator of the yield from a specific source using specific sources and conveyances for a project. Yield of a given offstream reservoir project can be determined by computing the difference between deliveries with and without the project and is discussed in the section describing CALSIM results.

Factors Related to the Upper Stony Creek Options

Factors other than potential water supply diversions, water supply contribution, and yield may be considered in evaluating the upper Stony Creek reservoir diversion options. Using Stony Creek as a water supply source may offer a number of unique advantages compared to other sources. Since the East Park and Stony Gorge diversions are from existing reservoirs, fishery impacts and their associated mitigation costs may be significantly less. While Stony Creek would not provide enough water for an offstream reservoir by itself, maximizing diversion from Stony Creek sources would provide opportunities to limit diversions from the Sacramento River, for example. Since potential Stony Creek diversions are at greater elevation than Colusa or Sites Reservoirs, no pumping is required and additional hydroelectric power may be generated. All of the other source options must be pumped up 120 to 320 feet from Funks Reservoir.

Finally, conveyance from these reservoirs to Sites or Colusa would be independent of existing conveyance systems. All of the other source options are dependent upon the Tehama-Colusa Canal, at least, to get water into Sites or Colusa. This independence described above means that water could continue to be conveyed to offstream storage after deliveries begin in the Tehama-Colusa and GCID service areas.

Project Operation Studies

Two important characteristics of a surface water project are the size of its increased water supply and the cost of the project. The new or additional yield that a proposed project could generate is predicted by conducting operation studies. This is an accounting process over a historic period using recorded or estimated streamflows. This accounting includes all water hypothetically supplied to, stored in, lost to seepage and evaporation, and released from the reservoir. Operation studies are performed using a computer-based hydrologic simulation model. DWR's model is titled CALSIM and allows an operation simulation of a project under investigation simultaneously with other major reservoir systems such as the Central Valley Project and the State Water Project over a historic period. The current operation simulation uses the 1922 through 1994 hydrologic sequence. CALSIM's predecessor DWRSIM was used extensively by CALFED in its programmatic evaluation of the water resources of the Delta and its tributaries.

For a project operation study, water is released on a schedule representing project water demands at some point in the future (in this investigation the year 2020). The difference between the total system water supply with and without the project under investigation is considered to be the water supply attributable to the proposed project. The model is run using average monthly flows; whereas the availability of water supplies from various streams is developed using average daily flow data. Although the model is running on monthly steps, the result is refined enough to determine water supply yield estimates that are acceptable for making comparisons between competing alternatives.

For this phase of the offstream storage investigation, 42 CALSIM operation studies were run. These studies include 3 base studies, 31 for the Sites Project, 4 for the Colusa Project, and 4 for the Thomes-Newville Project. These studies include various optional sources of water and conveyance facilities for filling the reservoirs to allow identification of a preferred source and conveyance alternative for each project. The 1993 operation studies for the Red Bank Project were considered adequate for this phase of evaluation.

For the Sites and Colusa Projects, seven possible diversion locations were considered as sources of water to fill the reservoir: the Sacramento River at Red Bluff Diversion Dam; the Sacramento River at the GCID pumps; the Sacramento River at Chico Landing; the Sacramento River at mile 158.5 (opposite Moulton Weir); the Colusa Basin Drain; Stony Gorge Reservoir; East Park Reservoir; Thomes Creek at the Tehama-Colusa Canal crossing; and lower Stony Creek at the Glenn-Colusa Canal crossing.

For the Thomes-Newville Project, five possible diversion locations were considered: Thomes Creek about 5 miles upstream from Paskenta; Stony Creek at Black Butte Lake; the Sacramento River at the Red Bluff Diversion Dam; the Sacramento River at the GCID pumps; and Thomes Creek at the Tehama-Colusa Canal crossing.

The general formulation of the CALSIM operation studies:

- Runs on a monthly basis for years 1922 through 1994.
- Uses estimated 2020 level of development.
- Uses a surrogate demand for project water supply. A surrogate demand is representative of currently unassigned project beneficiaries of the offstream

project yield. After project beneficiaries have been identified, an actual projected demand schedule will replace the surrogate in subsequent operation study runs.

- Models flows of both the Sacramento and San Joaquin River systems, with coordinated operation of CVP and SWP reservoirs.
- Generates data to estimate water supply, power use and power generation, fishery maintenance flows, recreation use, and Delta flow requirements.

The computation of project yield is one of the most useful outputs from an operation study. Yields are computed by comparing total system-wide deliveries for a proposed project to the deliveries under a base study. Table 3-7 summarizes the yields or increase in system deliveries for specific project formulations completed to date. Average and drought yields have been determined for each study. An average yield is the average annual increase in system deliveries from 1922 through 1994. Similarly, drought yield is the average annual increase in system deliveries during the 1928 through 1934 drought period.

Table 3-7. Increase in System Deliveries with Offstream Storage Project (taf)

Study #	T-C Canal	GCID Canal	New Canal	Chico Landing	Colusa Drain	East Park	Stony Gorge	Thomes Creek	Stony Creek	Assumptions	Avg Drought Yield (28-34)	Average Yield (22-94)
Base Studies:												
2												
6										Banks P.P.=10,300 cfs	79	184
7										Proposed Trinity flows	-134	-40
1.8 maf Sites Project:												
3	2100	1800									290	268
3b	2100										159	242
4	2100	1800			3000						310	277
5	2100	1800					1000				290	268
8	2100	1800					2000				296	282
8a							2000				36	98
9	2100	1800				800					292	275
9a	2100	1800				1000					293	277
10	2100	1800				1200					295	278
11	2100	1800								Banks P.P.=10,300 cfs	282	349
12	2100	1800					1000			Banks P.P.=10,300 cfs	299	354
13	2100	1800				800				Banks P.P.=10,300 cfs	295	351
14	2100	1800			3000					Banks P.P.=10,300 cfs	315	370

Table 3-7. Increase in System Deliveries with Offstream Storage Project (continued)

Study #	T-C Canal	GCID Canal	New Canal	Chico Landing	Colusa Drain	East Park	Stony Gorge	Thomes Creek	Stony Creek	Assumptions	Avg Drought Yield (28-34)	Average Yield (22-94)
15	2500	2500									294	282
16	2500	2500			3000						336	284
17			5000		3000						365	284
24	2100	2900									294	279
25	2100	2900			3000						336	286
38		5000			3000						331	286
1.8 maf Sites Project (cont'd):												
39		2900		2100	3000						349	285
40	2100		2900		3000						342	284
41	3200	1800			3000						339	287
42	5000				3000						338	288
43				5000	3000						360	284
44	2100	1800					1500				293	269
Sacramento River Flow Requirement:												
18	2100	1800			3000					Diversion Min=7,000 cfs	314	266
19	2100	1800			3000					Diversion Min=10,000 cfs	277	254
20	2100	1800			3000					Diversion Min=13,000 cfs	227	251
21	2100	1800			3000					Trigger=40,000 cfs	192	228
22	2100	1800			3000					Trigger=60,000 cfs	160	200
23	2100	1800			3000					Proposed Trinity	335	274
3.0 maf Colusa Project:												
30	2100	1800			3000					Diversion Min=10,000 cfs	277	313
31	2100	1800			3000					Trigger=60,000 cfs	159	236
32	2100	1800			3000					Proposed Trinity flows	398	328
33	2100	1800			3000					Banks P.P. =10,300 cfs	412	428
1.9 maf Thomes-Newville Project:												
34								5000	3000		146	213
35	2200							5000	3000		319	275
3.0 maf Thomes-Newville Project:												
36								5000	3000		146	248
37	2200							5000	3000		377	315

Three base studies were used in this set of modeling studies. In addition to the general formulation of the studies described above, Base Study 2 assumes the existing Banks Pumping Plant capacity restrictions per the Corps' 1981 Criteria, existing Trinity River instream flow requirements, and existing Sacramento River operating guidelines for flows. Base Studies 6 and 7 model the effect of increased Banks Pumping Plant capacity and proposed instream flow requirements for the Trinity River, respectively.

The proposed instream flow requirements for the Trinity River would reduce the average system yield by about 40 taf. The remaining studies that model these proposed flow requirements are compared against this lesser system yield indicated in Study 7. Other sensitivity analyses performed in this study set are related to potential flow requirements for the Sacramento River. The sensitivity analyses conducted for Sacramento River Diversion include trigger flows of 40,000 and 60,000 cfs and minimum downstream flows of 7,000, 10,000, and 13,000 cfs. A trigger flow is a minimum required flow that must be met once in a water year before diversion can be made to an offstream project. Once the trigger is achieved, only current restrictions related to Sacramento River flow would limit diversion. A minimum downstream flow is a continuing requirement that must be met at all times for diversion to offstream storage to be allowed.

The average project yields for North of the Delta Offstream Storage range from 98 to 428 taf. The 98 taf yield is associated with a 2,000 cfs conveyance from Stony Gorge Reservoir for the 1.8 maf Sites Project. This study formulation is not an actual alternative, but indicates the maximum amount of yield associated with the Stony Gorge source since no other sources would fill up storage space in the reservoir. The 428 taf yield is associated with the 3.0 maf Colusa Project with increased capacity at Banks Pumping Plant.

In addition to project yield, the operation studies also enable an assessment of impacts to Sacramento River flow and storage in existing reservoirs. By comparing "with project" flows and "without project" flows in specific reaches of the river, an estimate of streamflow changes related to project operation can be made. A comparison of storage in Shasta Lake and Lake Oroville with and without an offstream project indicates the potential change in storage levels in these existing reservoirs associated with project operation.

In general, the timing of flows in the Sacramento River is shifted a few months later in a given year. The shift in flows is mainly related to the exchange, where water that would have been released from Shasta Lake and delivered locally in the Tehama-Colusa and GCID service areas would instead be served by an offstream project. Water that is held in Shasta would then be released for other uses according to a demand schedule that generally requires water later in the year.

This flow information will be evaluated more thoroughly in the next phase of the investigation. In addition to general overview of flow impacts for the Sacramento River, scientists from the University of California will be assessing potential impacts of the flow changes in the river related to operation of an offstream reservoir project. Two studies will focus on river meander migration impacts and associated habitat evolution impacts. These studies are described in greater detail in Chapter 6.

The operation of an offstream project would also impact storage levels in existing reservoirs. Again, changes in the end-of-month storage in Shasta Lake are likely related to the exchange described above. Another factor that appears to affect both Shasta and Oroville is related to the additional storage that would be created by an offstream project and adjustments needed to operate that additional storage with the existing projects. More evaluation of end-of-month storage impacts is anticipated during the next phase of the investigation.

Water Conveyance Alternatives

This study investigated alternative conveyance systems designed to move water from sources including the Sacramento River and its tributary streams as well as offstream storage projects. For the Sites and Colusa Projects, the optional conveyances considered are identical and consist of the following: existing or expanded Tehama-Colusa and Glenn-Colusa Canals; a new canal from the Colusa Basin Drain and/or the Sacramento River near Moulton Weir; a new diversion on the river near Chico Landing; and a canal intertie to the Tehama-Colusa or Glenn-Colusa Canals. These primary options were combined in different ways with supplemental conveyance from river tributaries and resulted in the variations described below and shown on Figure 3-1. Descriptions and approximate cost estimates for the conveyance system alternatives investigated for Sites and Colusa are given below:

Alternative

I. Would use the existing Tehama-Colusa and Glenn-Colusa Canals from their diversions near Red Bluff and Hamilton City, respectively, to a terminal location near Funks Reservoir. A short section of new canal and pumping plant would connect the Glenn-Colusa Canal to Funks Reservoir. The cost of this alternative is estimated at $110 million, mostly for the new canal section and pumping plant. This alternative could deliver a maximum of 3,900 cfs from the Sacramento River to Funks Reservoir. Operation studies 3 and 11 reflect this alternative, with average yields for Sites of 268 and 349 taf for existing and enlarged pumps at Banks, respectively.

II. Is the same as alternative I except that both canals would be enlarged slightly to carry 2,500 cfs each for a total of 5,000 cfs from the river to Funks. The total cost would double to around $220 million, while the carrying capacity would increase 28 percent. Under this alternative, the costs of pumping plants and other conveyance facilities would be approximately equal to that of Alternative I. This alternative is reflected in operation study 15, with a Sites Project average yield of 282 taf.

III. This alternative would use the existing 2,100 cfs capacity in the Tehama-Colusa Canal and 2,900 cfs capacity in an enlarged Glenn-Colusa Canal, combined with 3,000 cfs from the Colusa Basin Drain. The drain water would be conveyed via a new canal and two pumping plants to the Glenn-Colusa Canal for transfer to Funks Reservoir by way of the same connector used in alternatives I and II. The total diversion capacity to Funks Reservoir would be 8,000 cfs and the estimated cost would be about $490 million. This alternative is modeled in operation study 25 and would have an average yield of 286 taf for Sites Project.

IVA. This alternative would use the enlarged Glenn-Colusa Canal to carry 5,000 cfs plus 3,000 cfs from the Colusa Basin Drain via the new canal. The total diversion capacity to Funks Reservoir would be 8,000 cfs and the estimated cost around $550 million. Operation study 38 reflects this alternative conveyance for the Sites Project, with an associated average yield of 286 taf.

IVB. Same as Alternative IVA, but with a new 2,100 cfs diversion near Chico Landing connecting to the Glenn-Colusa Canal instead of an increase in pumping capacity at the existing Hamilton City pumping plant. The total diversion capacity to Funks Reservoir would be 8,000 cfs and the estimated cost is approximately $500 million. This alternative is shown in operation study 39, with an average yield of 285 taf for Sites Project.

V. Would consist of a new 5,000 cfs river diversion opposite Moulton Weir combined with a 3,000 cfs diversion from the Colusa Basin Drain. Both sources of water would be conveyed to Funks Reservoir via the new canal. The total diversion capacity to Funks Reservoir would be 8,000 cfs and the estimated cost $580 million. See operation study 17, with an average yield of 284 taf for Sites.

VIA. Would use existing 2,100 cfs Tehama-Colusa Canal combined with new 2,900 cfs Sacramento River diversion and canal opposite Moulton Weir, plus 3,000 cfs from the Colusa Basin Drain. Total diversion capacity to Funks Reservoir is 8,000 cfs and the estimated cost would be around $470 million. This alternative is shown in operation study 40, with an average Sites yield of 284 taf.

VIB. Same as Alternative VIA except with the capacity of the Glenn-Colusa Canal reduced to the existing 1,800 cfs and the new Sacramento River diversion increased to 3,200 cfs. Total diversion capacity would remain the same at 8,000 cfs and the total costs would be reduced to about $450 million.

VIIA. New 5,000 cfs Tehama-Colusa Canal diversion and canal expansion to Funks Reservoir plus 3,000 cfs from the Colusa Basin Drain via the new canal. Total diversion capacity to Funks Reservoir would be 8,000 cfs and the estimated cost would be around $870 million. Operation study 42 shows an associated average yield of 288 taf.

VIIB. Same as Alternative VIIA except that the Tehama-Colusa Canal water would be diverted at Chico Landing via new diversion. Diversion capacity would be the same and estimated cost around $730 million. Operation study 43 indicates an average yield of 284 taf for Sites.

VIIIA. Includes 1,500 cfs tunnel diversion from Stony Gorge Reservoir combined with the existing 2,100 and 1,800 cfs diversions via the Tehama-Colusa and Glenn-Colusa Canals, respectively. The total diversion capacity to Sites or Colusa Reservoirs would be 5,400 cfs and the estimated cost around $420 million. Operation study 44 shows an average yield of 269 taf for Sites.

VIIIB. Same as Alternative VIIIA except that Stony Creek water would be diverted from East Park Reservoir via a 1,200 cfs tunnel. Total diversion capacity to Sites or Colusa Reservoirs would be 5,100 cfs and the estimated cost approximately $230 million. Operation study 10 indicates an average yield of 278 taf for Sites.

In addition to the above conveyances, new or enlarged river diversion and canal pumping plants would be required in all of the conveyance alternatives.

Pumping plant capacities would range from approximately 1,100 to 6,100 cfs, with pumping heads of approximately 20 to 110 feet (excluding the final Funks to Sites Reservoirs lift). These pumping costs were not included in the comparative cost estimates above.

No decision on the preferred conveyance alternative has been made yet. Future investigation of the environmental impacts associated with these alternatives must be completed before a preferred source and conveyance alternative can be selected.

Figure 3-1. Sites Reservoir Conveyance Alternatives

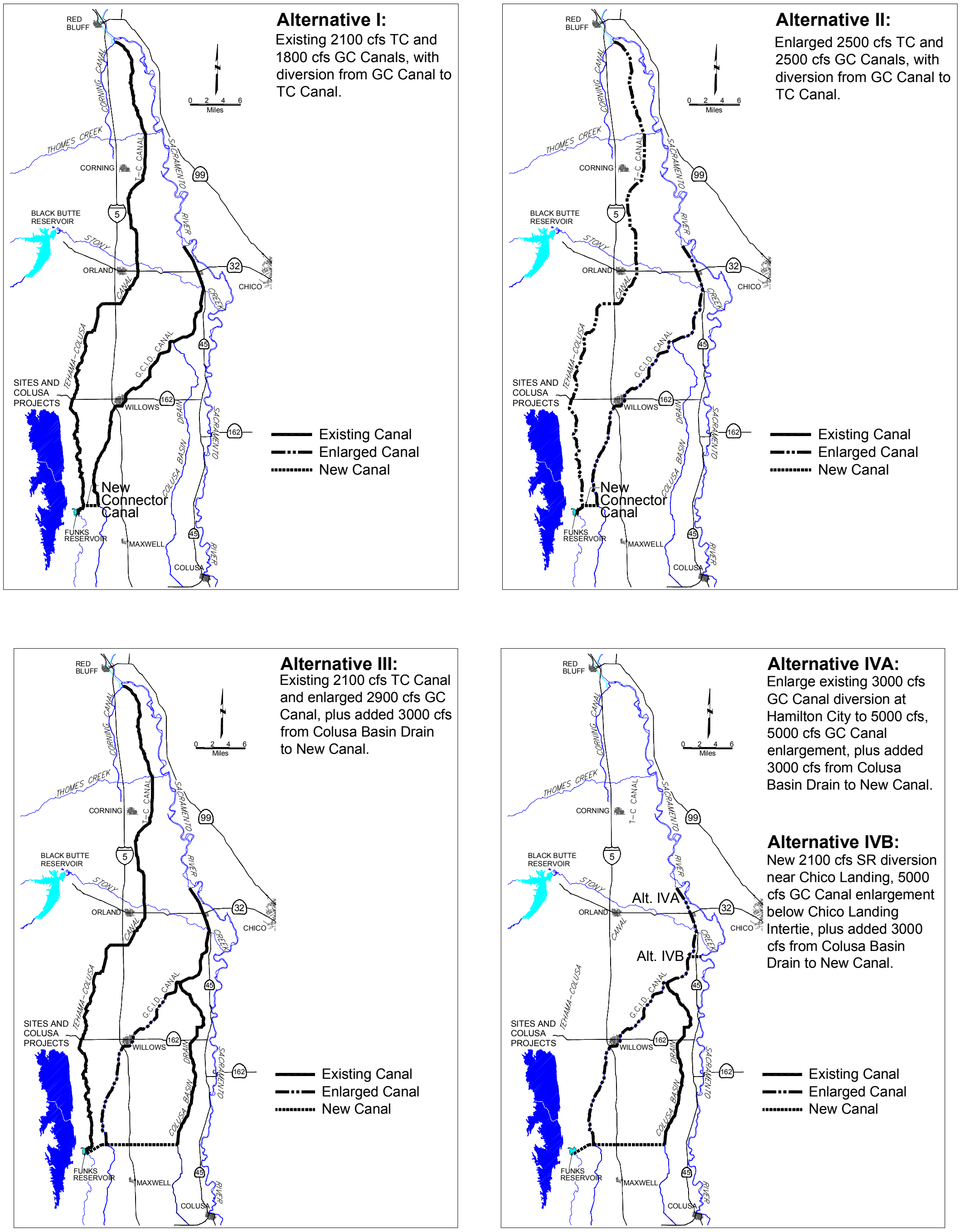
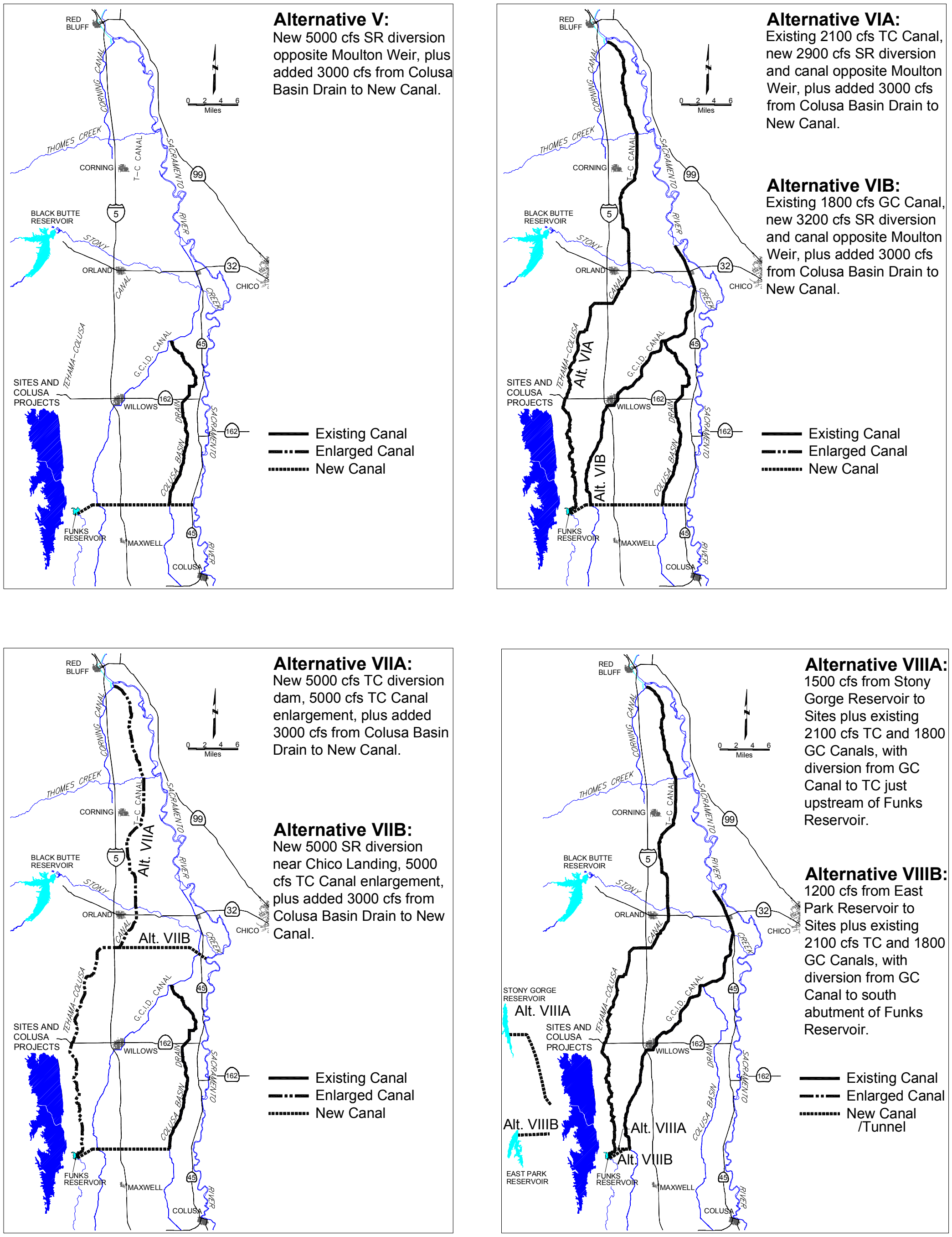


Figure 3-1. Sites Reservoir Conveyance Alternatives (continued)



Power Generation/Consumption and Potential Pumpback Operation

DWR's State Water Project Analysis Office performed a cursory study of power consumption, generation (including potential pumpback hydropower operation), related costs, and revenues associated with operation of the Sites

Project. The pumpback power generation potential of other projects will be evaluated later.

This study estimated power costs associated only with the transfer of water between existing or enlarged Funks Reservoir and a 1.8 maf Sites Reservoir. It did not include costs associated with any additional pumping/generating plants required to transport water from the river or other water supply sources to Funks Reservoir. Nor does the study include the cost of energy required to initially fill Sites Reservoir.

Two alternative operations were considered:

1. Operation with no increased storage at Funks Reservoir, referred to as minimal operation.
2. Operation with an enlarged Funks Reservoir of around 8,000 af capacity to maximize power operations referred to as optimized operation.

For these two categories, the following alternative operation modes were evaluated as summarized in Table 3-8.

- **Minimal Seasonal Operation.** No additional forebay storage beyond that in existing Funks Reservoir would be required for this operating option. It would simply pump water into the Sites Reservoir for storage on a 24-hour per day schedule as required during the winter and release water through Funks Reservoir for irrigation on the same continuous schedule during the summer. Pumping and generation would occur on a 24-hour basis regardless of hourly or daily power cost fluctuations. The average annual net power cost (cost of power consumed minus revenue from sale of power produced) resulting from this operation is estimated at around $723,000, or approximately $11.4 million in present worth net power cost over the life of the project (50 year period of analysis, 6 percent discount rate).
- **Optimum Seasonal and Pumpback Operation combined.** This option would require construction of a larger Funks or similar forebay (to around 8,000 af) and another pumping plant to raise water from the Tehama-Colusa Canal into the enlarged forebay. It would take advantage of pumpback opportunities whenever economically advantageous by pumping at night when power costs are lowest, and generating (by releasing reservoir water) during the day when power values are highest. After the project pumped or released the desired amount of water for seasonal operation, any remaining time could be used for full pumpback operation. This operation just transfers water back and forth between Sites and Funks Reservoirs for the sole purpose of generating power revenues. This would only be done when the difference between peak and off-peak power rates was large enough to more than offset the cost of power consumed by system inefficiencies and the operation, maintenance, and replacement costs. In other words, pumpback would only be implemented at times when substantial net revenues would be realized. The average net power revenue benefits which could result from this operation were estimated at around $2,481,000 per year or approximately $39 million in equivalent present worth over the life of the project.

Net revenues from pumpback operation must be balanced against major additional pumpback storage costs such as: (1) constructing and maintaining an 8,000 af forebay; (2) constructing and maintaining an additional pumping plant to lift water from the Tehama-Colusa Canal to the new enlarged forebay; and (3) increased pumping/generating capacity, maintenance, and replacement. Although precise estimates have not been made, these costs would be substantial, possibly exceeding the $39 million present worth of pumpback storage power benefits. More work will be performed on this potential project feature as the OSI continues. However, it does not appear that pumpback storage offers a major advantage to a project whose overall cost will substantially exceed $1 billion. Therefore, pumpback power operations appears to be a relatively inconsequential factor in determining project feasibility, and may not be justified.

Table 3-8. Summary of Pumpback Operation Cost and Revenues

(Only pertains to water conveyed between Funks and Sites Reservoirs)

MINIMAL OPERATION (No Enlargement of Funks Reservoir)

Mode of Operation	72-Year Period	Annual Operation				
		Energy Consumption (1,000 MWH)	Energy Production (1,000 MWH)	Energy Cost ($1,000)	Energy Revenue ($1,000)	Revenue Minus Cost ($1,000)
Seasonal	Max	350	261	8,991	6,331	-2,660
	Min	0	0	0	0	0
	Avg	107	75	2,657	1,925	-732

OPTIMIZED OPERATION (Enlargement of Funks Reservoir to around 8,000 af)

Combined Seasonal pumpback	Max	800	625	15,032	18,363	3,331
	Min	223	167	3,771	4,861	1,090
	Avg	554	418	9,892	12,373	2,481

(a) The study this table summarizes was based upon assumption of a very efficient schedule with no environmental restrictions. This cannot be achieved in actual operation; therefore, this table represents the maximum power revenues potentially available.

(b) Costs of maintenance and wear on the units and replacement costs are considerable and may affect the decision to use pumpback operation when the on-peak/off-peak price differential is small.

Sites Reservoir Recreation

The recreation use potential of Sites Reservoir is substantial, though limited somewhat by steep terrain and potential, widely varying, reservoir elevations due to operation. The nearby, but much smaller, Black Butte Lake received an average of 335,000 recreation user days annually since 1985. Visitation at Sites Reservoir is anticipated to be higher because of its attractive larger size and proximity to population centers. There are several potential developable recreation areas around Sites Reservoir.

Five major potential recreation areas around Sites Reservoir were identified in this investigation and are described below:

- Stone Corral Recreation Area (225 acres) is located immediately north of Sites Dam. It could support approximately 50 campsites and possibly a two-lane boat ramp. Shoreline fishing would be good due to deep water and the area offers excellent views because of its higher elevation. A trail system and interpretive displays would be suitable.
- Saddle Dam Boat Ramp (600 acres) is located at the north end of the reservoir adjacent to several of the project saddle dams. This area is mildly sloping and suitable for boat ramp construction and associated parking. Also, this area would be readily accessible if the Maxwell-Lodoga Road was relocated around the north end of the reservoir. Day-use facilities such as a swim beach and picnic area could be located on the slopes surrounding a boat ramp. No campsites are proposed at this location due to its lack of vegetation and exposed character.
- Peninsula Hills Recreation Area (325 acres) is located on the west shore of Sites Reservoir on what would be a large peninsula. This area contains a series of small coves that would be excellent for fishing and hiking. It is suitable for a large campground of around 200 sites that could be completed in stages. There are two potential boat ramp locations. Access would be from the relocated Sites-Lodoga Road, but about 2 miles of additional new road would have to be constructed.
- Lurline Headwaters Recreation Area (200 acres) is located on the ridge forming the southeast shore of Sites Reservoir and is characterized by an open meadow surrounded by oak grassland and steep hills overlooking the reservoir. This area could support both camping and day-use activities such as hiking to a nearby 1,282-foot-high peak with outstanding views. Approximately 50 campsites, one or two group sites, and numerous picnic sites could be constructed on the 50 acres of relatively level land in this area. However, this area would not have vehicle access to the shoreline or a boat ramp, because of the steep terrain. About 2 miles of rough existing road would need to be upgraded to access this area.
- Dunlap Island Boat-In Facilities (50 acres) could be located near the southwestern shore across from the Sites townsite. This island would provide boaters a camping area near a secluded bay. Enough suitable land exists to support construction of approximately a dozen primitive campsites with sanitation facilities, but with no treated water supply.

Other recreation features that have been considered could also become a part of the Sites Project include:

- Sites Reservoir Loop Trail for hiking, biking, and equestrians extending around the reservoir and connecting all the shoreline recreation areas. Much of the trail would run along the crest of Logan Ridge that provides outstanding views of the Sacramento Valley and surrounding mountain ranges.
- Fishing access points could be constructed at numerous locations along the relocated Sites-Lodoga Road.
- Pre-project fishing enhancement could be accomplished by stocking the numerous existing ponds in the reservoir area with brood-stock fish to accelerate development of a reservoir recreational fishery.

- A Stone Corral Creek coldwater fishery could be developed immediately below Sites Dam.

Colusa Project

DWR's interest in the Colusa Project began in the 1960s as part of a Klamath-Trinity River Development alternative conveyance system that would terminate at Colusa Reservoir. The November 1981 Bulletin 76-81 concluded "data indicates that the incremental cost of storage at Colusa would be excessive in comparison to the storage costs of Sites Reservoir."

The Colusa Cell, at the maximum water surface elevation of 520 feet, occupies all of the 14,000 acres immediately north of Sites Reservoir. The Colusa Cell adds 1.2 maf of storage to Sites, for a total of 3.0 maf for Colusa Reservoir. However, four more major dams along Logan Ridge—Prohibition, Owens, Hunters, and Logan Dams—and seven saddle dams are required to form the reservoir. There is approximately a four to one ratio between the dam volume of Colusa compared to Sites at the maximum 520-foot water surface elevation.

The Colusa Project, like Sites, would be filled by winter water, surplus to downstream needs from the Sacramento River and/or tributaries. Project appurtenances including inlet, outlet, spillway, pumping/generating plants, and forebay at Golden Gate Dam would be the same as for the Sites Project. However, with the larger Colusa Reservoir capacity, the size of most of these appurtenances would be increased proportionately. Considerable engineering and geologic work has been performed at Sites; Colusa is not as well defined and requires additional work to bring it up to an equivalent status. This work would be performed in the near future, subject to continuing screening.

There are no State or county roads and only one known permanent resident within the additional area required to form Colusa Reservoir. Also, the only known utilities are those that service the residents; therefore, the relocation of people and structures for Colusa will be essentially the same as for Sites. Colusa would flood a primary road relocation route for Sites. This would probably result in the Maxwell-Lodoga Road being located around the south end of Colusa Reservoir.

Alternative Sources of Water

Colusa at 3.0 maf can take advantage of a greater water supply and produce a larger yield than Sites at 1.8 maf. However, the potential sources of supply for Colusa are the same as those for Sites. The size of the diversion and conveyance system can be increased to expand the supply. Determination of the near optimum match between reservoir capacity and conveyance size is made by comparing water yields (from operation studies) with the estimated project costs to generate these yields. This sizing selection process will be emphasized later in this investigation. More operation studies covering numerous sizing options and feasibility-level cost estimates are needed to determine optimum project size. At this point in the investigation, the same alternative sources and sizes of water conveyances are under consideration for both the Sites and Colusa Projects. Continued project formulation studies will evaluate the optimum conveyance sizing compared to reservoir size.

Project Operation Studies

The results of the four Colusa Project Operation Studies run to date are shown in Table 3-7. The 1922 through 1994 period average annual project yield estimated by studies ranged from 236 to 428 taf, depending on assumptions related to potential operations. All of the studies run were for a source and conveyance alternative including existing Tehama-Colusa and GCID canals and a 3,000 cfs diversion and conveyance from Colusa Basin Drain. Yields associated with alternative Colusa Project formulations can be estimated based on Sites Project studies and the four Colusa studies. In general, yields are diminished when potential instream requirements for the Sacramento River are included and a smaller reduction occurs when proposed Trinity River requirements are included. Comparison of Sites and Colusa using the same assumption sets indicates an average yield increase of 16 to 23 percent. The largest improvement is for critical years with expanded Banks Pumping Plant capacity, where the yield improves from 315 taf for Sites to 412 taf for Colusa, a 31 percent increase. This correlates with the fact that Colusa Reservoir is 66 percent larger than Sites. Additional operation studies will be run if the study of Colusa continues, using the CALSIM model and more detailed operational criteria.

Water Conveyance Alternatives

The potential Colusa Project water conveyance alternatives are identical to those for Sites but the higher capacity options may be a better match for Colusa due to its larger capacity. Future operation studies and cost comparisons would more clearly identify the water supply needs of the Colusa Project. Earlier studies of Colusa located the inlet/outlet and pumping/generating facilities at Logan Dam instead of Golden Gate Dam. This was done to shorten the conveyance system distance from the Tehama-Colusa and Glenn-Colusa canals Sacramento River diversions. However, for this comparative study to determine relative project feasibility, Golden Gate Dam has been designated as the water inlet/outlet location for both projects based on the following:

- The Tehama-Colusa and GCID canals are much closer together near the Golden Gate Dam site and a connector canal between them would be less expensive to construct.
- Golden Gate is a superior input location for water from the Colusa Basin Drain and the Sacramento River below Chico Landing because it would collect more water farther down the basin and the canal alignment would not pass through sensitive public waterfowl areas.
- Considerably more study effort would be required to evaluate another inlet/outlet location and the probability that it would significantly impact project feasibility is small.
- If after further study the Colusa Project is determined to be superior to Sites, further consideration can be given to the relative merits of locating inflow/outflow facilities at Logan Dam instead of Golden Gate Dam.

Recreation Opportunities

Recreation opportunities for the Colusa Project are similar to those for Sites. A more detailed investigation of these opportunities would be initiated if study of the Colusa Project continues.

Comparison of the Sites and Colusa Projects

The Offstream Storage Investigation frequently confirms conclusions from older studies that evaluated similar projects. Despite the fact that many of the facilities for the Sites and Colusa projects would be the same or similar, the DWR investigation of the projects around 1980, as reported in Bulletin 76-81, indicated that the unit cost of storage (dollars per acre foot of storage) and yield (dollars per acre foot of yield) for Colusa is considerably higher than for Sites. These relatively high unit costs were primarily due to the very large embankments required by the additional dams and seven saddle dams that are required to expand Sites Reservoir to the larger Colusa Reservoir. This current investigation estimates the embankment volumes required for Sites and Colusa reservoirs at about 24 and 100 million cubic yards respectively so that Colusa requires about four times the embankment volume as Sites. Preliminary estimates indicated the total unit cost of yield for Colusa is approximately double the unit cost of water yield of Sites.

Although feasibility level determination of these project's costs requires further evaluation, comparable historic cost estimates updated to the present confirms the findings of earlier work. Supporting information and additional factors relevant to a comparison of the Sites and Colusa projects are listed below:

- Assuming a basic formulation for source and conveyance – where the preferred conveyance includes a new canal from Colusa Basin Drain and existing GCID and Tehama-Colusa canals, with the expanded Banks Pumping Plant—the unit cost of the Colusa Project would be approximately double that of Sites and the average annual water yield would only increase by around 30 percent.
- The Colusa Reservoir inundation area would approximately double the inundation area of Sites. If the associated environmental impacts and mitigation costs also double, then a 100 percent increase in impacts would again be associated with a 30 percent increase in yield as compared to Sites.
- The additional dams required to form Colusa Reservoir are extremely long and located in an area with less sandstone than at the Sites and Golden Gate dam sites. This will increase the haul distance for sandstone to Colusa in comparison with Sites by as many as ten miles. Sandstone, in large volumes, is required for dam shell and slope protection material.
- The foundation geology of the Colusa Project dam sites in comparison to the Sites Project dam sites is generally weaker, more deeply weathered, fractured, and permeable. Colusa dam sites will require more corrective actions to the foundations such as additional overburden stripping and grouting, which will increase the cost of construction.
- Reservoir evaporation at Colusa would be approximately double that at Sites. The estimated average annual evaporation from Colusa Reservoir would be around 90 taf. This is water that must be pumped into the reservoir, but is not available for water supply or power recovery purposes when reservoir releases are made during the irrigation season.

Thomes-Newville Project

The Thomes-Newville Project would include a 1.9 to 3.0 maf offstream reservoir located on North Fork Stony Creek. It is about 18 miles west of Orland and 6 miles upstream of existing Black Butte Lake. The water supply for this project could come from Stony Creek, Thomes Creek, and the Sacramento River. The Thomes-Newville Project received extensive study by DWR from 1976 through 1982 and a major DWR document titled *Thomes-Newville and Glenn Reservoir Plans: Engineering Feasibility* reported on this work. The long and interesting history of water project planning in the Stony and Thomes Creek basins is summarized in an appendix of this report. The current Offstream Storage Investigation is using this past work as a basis, but is incorporating substantial changes in water project planning criteria that have occurred since then. Because of the large amount of past engineering studies at this site and our concentration to date with investigation of the Sites and Colusa Projects, most Thomes-Newville Project information presented here is based on historic work.

The basic components of the Thomes-Newville Project are: (1) a 300-foot to 400-foot Newville Dam at the historic Newville Townsite; (2) an 80-foot to 180-foot high saddle dam at Burrows Gap; (3) a southern saddle dam at Chrome for normal water surface elevations exceeding 920 feet; (4) a pumped diversion and conveyance system from Black Butte Lake; 5) a small diversion dam and gravity diversion from Thomes Creek; and 6) a pumped diversion and conveyance system from the Tehama-Colusa and/or Glenn-Colusa Canals if needed for larger reservoir sizes.

More stringent fishery requirements will likely be applied on Thomes Creek, which may require a fish passage at the diversion location. In view of Thomes Creek's heavy sediment load, construction and operation of these structures may be difficult and expensive. Future study would address these issues in greater detail if required.

In addition, several low saddle dams may need to be constructed along Rocky Ridge, the eastern boundary of the reservoir, depending on the selected reservoir elevation. The roads through the reservoir inundation area to Paskenta, Round Valley, and Elk Creek would be rerouted around the eastern and northern boundary of the reservoir.

Topographically, Newville Reservoir is very efficient. It requires a relatively small volume of dam embankment material per unit of water stored. Also, the reservoir bottom is relatively wide, long, and flat so that the reservoir area only increases around 20 percent (14,000 to 17,000 acres) between the capacities of 1.8 and 3.0 maf. In comparison, the Colusa Project at 3 maf capacity occupies 28,000 acres, or 65 percent more area.

The main challenges of the Thomes-Newville Project are providing an adequate water supply from nearby streams and mitigating for environmental impacts which have not all been evaluated yet.

Alternative Reservoir Capacities

The most recent (1980) DWR report on the Thomes-Newville Project examined three sizes: 1.4 maf at normal water surface elevation of 868 feet; 1.7 maf at 887 feet; and 1.9 maf at 905 feet. For the CALFED Offstream Storage Investigation, a reservoir size up to 3 maf is also included. This larger reservoir size analysis is based on studies performed by DWR around 1966. A 3.0 maf Newville Reservoir would be created at a normal water surface elevation of 980 feet. These older studies will be updated and modified in the future along with feasibility-level engineering analysis at the Sites Project.

The primary sources of water for a Thomes-Newville Project up to 2 maf capacity are Stony Creek at Black Butte Lake, and Thomes Creek above Paskenta. For a reservoir size above 2 maf or if fishery-related facilities are too costly for the Thomes Creek diversion, additional water from the Sacramento River would be needed to fill the reservoir in a reasonable period (less than 10 years).

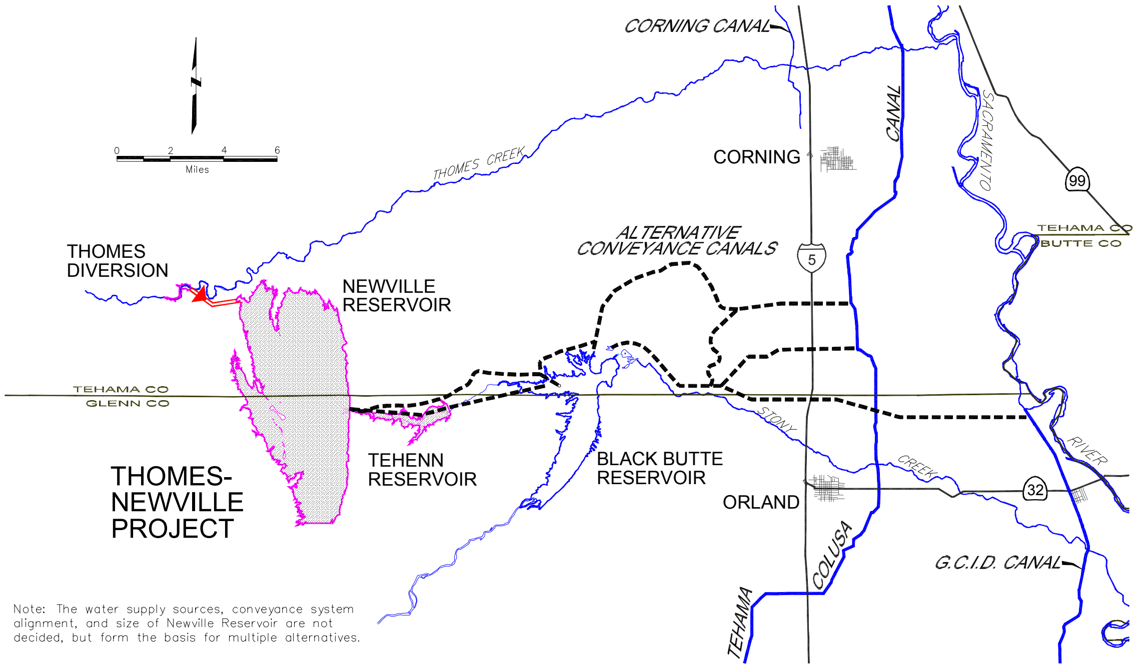
Diversions from Stony and Thomes Creeks for reservoir sizes less than 2 maf are evaluated in the 1980 Engineering Feasibility Report. Stony Creek water from Black Butte Lake would be conveyed westward via an excavated deepening of the channel of North Fork Stony Creek and pumped into a small reservoir named Tehenn. This small dam and reservoir was planned for location on the north fork about midway between Black Butte Lake and Newville Dam site. A small dam 112 feet high and 2,500 feet long would form the 32,500 af Tehenn Reservoir at elevation 610 feet. Because this reservoir would flood a cemetery of historic importance, future studies will evaluate other conveyance alternatives.

Three potential diversion dam locations on Thomes Creek to convey water through the low divide to Newville Reservoir were investigated in studies around 1980. Because the lower sites required taller dams and flooded more land area critical to migratory deer herds, the upper dam was considered most desirable. In addition to typically lower costs, a low dam is more favorable to migrating fish. Therefore, the dam site farthest upstream is still the favored alternative for a Thomes Creek diversion. Further investigation will determine whether a ladder and screen would be required for fish. The economic and environmental feasibility of these facilities has not been determined. After diversion, the Thomes Creek water (minus required instream flows) would be conveyed to Newville Reservoir via a 2-1/2 mile canal.

If additional water is needed due to larger reservoir sizes or an inability to divert water from Thomes Creek, it could be obtained from the Sacramento River by diverting from Tehama-Colusa and/or Glenn-Colusa Canals. This water could be conveyed via new facilities shown on Figure 3-2. Lift pumps would be required. Several alternative conveyance system alignments have been investigated at an initial level and the results are contained in the report titled *Sites Reservoir Conveyance Study*. Considerable additional design and cost estimating work needs to be done on the Thomes-Newville Project facilities.

Optional sources of water supply for the Thomes-Newville Project are similar to those for Sites and Colusa. Local sources potentially have a more significant role for Thomes-Newville. In the original project formulations, water from the Sacramento River is included in all of the Sites and Colusa alternatives. For Thomes-Newville, Sacramento River water would be imported only if water from Stony and Thomes Creeks is not feasible or adequate to fill the reservoir. The streamflow volumes and divertible flows associated these streams are shown in Tables 3-3 and 3-4.

Figure 3-2. Thomes-Newville Project Alternatives



Operation Studies

Four operation studies have been run for the Thomes-Newville Project: two at the 1.9 maf size and two at the 3.0 maf size as shown on Table 3-7. The average annual yield of these projects for the 1922 through 1994 period ranges from 213 taf to 275 taf for the 1.9 maf size, and 248 taf to 315 taf for the 3.0 maf size. These yield estimates are based on project formulations that include 5,000 cfs conveyance from Thomes Creek and 3,000 cfs conveyance from Black Butte Lake. The larger yields are for adding 2,200 cfs conveyance associated with Tehama-Colusa Canal diversion to Black Butte and increased diversion to Newville Reservoir. Drought year yields are generally less for the alternatives that only include the local sources and greater when the Sacramento River is included as a source. More operation studies will have to be run in the future as project sizing and conveyance features become more defined. For the present, these operation studies indicate that the Thomes-Newville Project has roughly the same new water supply capability as comparable sizes of the Sites and Colusa Projects.

Operation of the Thomes-Newville Project would be similar to that of Sites and Colusa, in that winter water surplus to needs and rights in the watershed would be diverted and stored for release mainly during the irrigation season. The water released would be used entirely within the Colusa Basin in exchange for Sacramento River water that would otherwise have been diverted to serve this area. This undiverted river water would remain as storage in Shasta Lake until it is released on a different schedule designed to serve a combination of urban, environmental, and agricultural purposes.

Recreation Opportunities

Major recreational attributes of Newville Reservoir would include a large water surface that would be desirable for large motorboats, sailboats, and houseboats. The west shore islands would attract boat anglers and boat-in campers and would provide ideal houseboat anchorage. A hiking and riding trail would follow the crest of Rocky Ridge along the eastern shore of the reservoir and offer attractive vistas and secluded fishing spots. Boat-in, hike-in, or ride-in camps on the west shore could provide access to the reservoir or the backcountry of the Mendocino National Forest.

Fourteen recreation sites were identified around the reservoir that could accommodate up to 13 boat ramp lanes, 150 to 200 picnic sites, more than 100 camp sites, more than 1 mile of beach, and 5 to 10 miles of trail. If these areas are developed, they could support 500,000 to 1,000,000 recreation days annually, a typical level of use for this size project.

Red Bank Project

The Red Bank Project would be located on the South Fork of Cottonwood Creek and on Red Bank Creek approximately 17 miles west of Red Bluff. Two main dams—Dippingvat on Cottonwood Creek and Schoenfield on Red Bank Creek—and two smaller dams—Lanyan and Bluedoor on small tributaries of Red Bank Creek—would form this project. The smaller dams facilitate conveyance of water from Cottonwood Creek to Schoenfield Reservoir.

With a total storage of about 350 taf, the Red Bank Project is by far the smallest of four alternatives evaluated. Its main potential benefit is its ability to supply water directly to the entrance to the Tehama-Colusa Canal instead of diverting this water from the Sacramento River. This operational feature could allow the Red Bluff Diversion Dam gates to be raised for a longer period; thus reducing the dam's impact on the fishery.

The Red Bank Project was investigated by DWR in the late 1980s through the early 1990s and is documented in several DWR reports. The Red Bank Project is not a typical offstream storage project because one of the two major dams blocks access to approximately 132 square miles of South Fork Cottonwood Creek watershed which contains anadromous fishery habitat. Also, the estimated cost of the project steadily increased as the study progressed and the water supply decreased as downstream fishery flow needs were identified.

DWR recently investigated the possibility of lowering and modifying Dippingvat Dam to allow fish passage around it, but this cursory evaluation indicated that the required actions would increase costs and decrease yield without ensuring unhindered fish passage. Even though the size and cost of Dippingvat Dam would be reduced, savings would likely be more than offset by greater conveyance system costs, fish ladder and screen construction costs, and the large reduction in reservoir capacity which also reduced flood control and water supply benefits.

Because the Red Bank Project was intensively studied around 1993 and because of its small size, and potential for adverse fishery impacts, little additional engineering work on this project has been conducted. At this point, it seems likely that CALFED may defer additional work on this project in favor of emphasis on the Sites and Thomes-Newville Projects. However, an inventory of environmental resources is being completed which will help determine the environmental feasibility of this project.

Alternative Sources of Water

Unlike the other three alternative projects, the Red Bank Project's only sources of water are the watersheds above the two main dams. More than 70 percent of its 135 taf/yr average annual water supply comes from South Fork Cottonwood Creek, and the remainder comes from Red Bank Creek. In contrast, Schoenfield Reservoir on Red Bank Creek would provide around 70 percent of the reservoir storage. South Fork Cottonwood Creek provides the main water supply and Red Bank Creek provides the main storage area. No water would be conveyed from any other sources.

Operation Studies

Operation studies for the Red Bank Project run in 1993 were considered sufficient for this phase of investigation. These studies were for a stand-alone project that was not dependent on other existing water supply projects, as the previously described CALSIM studies are. A coordinated study should be performed at a later date if the project survives screening analysis. Instream fishery flow needs in South Fork Cottonwood Creek are estimated to range from 30 cfs in the summer to 60 cfs in the winter with a couple of 120 cfs flushing flows of eight days duration each. These flow needs were incorporated into the 1993 study. A 70 taf flood control reservation in Dippingvat Reservoir was also included. The firm new water supply for an agricultural demand schedule estimated by this operation study is 43 taf/yr. This yield estimate could change considerably if different assumptions were made concerning fish releases, flood control reservation, water demand schedule, or other project criteria. No water from this project would be released directly to the Sacramento River because of concerns over the potential impacts of its warm summer temperature.

One significant issue that past studies have not addressed is percolation to groundwater along 16 miles of Red Bank Creek of water released from Schoenfield Reservoir. This percolation loss could be substantial and should be addressed if study of the Red Bank Project continues.

Recreation Opportunities

The recreation potential at Schoenfield Reservoir is much greater than at Dippingvat due to the flatter terrain around the reservoir and the less severe drawdowns required for flood control. Schoenfield Reservoir could be developed for fishing, camping, picnicking, boating, hiking, and hunting. Earlier estimates indicated that the entire Red Bank Project has the potential to support an average of around 100,000 recreation user days annually.

Offstream Storage Project Formulation

Project formulation is a critical component of surface water storage investigations. The objective of project formulation is to 1) select a project which will have the least environmental impacts, and 2) optimize project benefits by selecting the most feasible location, size, and configuration for the various project features such as storage, conveyance, and diversion structures. Many combinations of these separate facilities are possible, but the cost effectiveness of different configurations varies widely.

At its heart, the project formulation process is technically rigorous and requires the analysis of numerous options. However, in practice the complexity of the process is reduced by making simplifying assumptions and developing reasonable criteria, and by the limitation of practical realities. Some of these potentially limiting factors include environmental considerations, hydrology and water supply availability, water demand projections, projected energy demands and costs, and the level of development in and around the project. Evaluating these and other factors requires as much art (subjective analysis) as science and, therefore, the process may rely heavily on historic project operations and experiences. For example, many reservoirs have different operating rules applied to them over their life. The trend today is to operate most major water projects as a unit in order to maximize total combined water supply benefits, whereas most projects were planned using a stand-alone operating strategy. This tendency for water management operations to change over time is considered beneficial and is known as adaptive management. It is a strong motivator for building maximum flexibility into current project formulations. Current project formulation studies attempt to combine engineering possibilities with cost and financial considerations, biological impacts (environmental), and public acceptability.

The first step in project formulation is to identify reservoir site alternatives, water supply sources, and possible conveyance facilities. Alternatives that are not practicable or are environmentally harmful are then screened out. The next step of the project formulation is to perform a series of initial project operation studies for remaining alternatives. These operation studies estimate the relative level of water supply, or yield of various sized reservoirs, water conveyance systems, and water supply sources for various project alternatives. After feasibility-level cost estimates are made, formulation studies combining various sizes of reservoirs and water supply systems will be made. Also, opportunities for maximizing power revenues will be explored in greater detail. Increasingly refined project formulation studies will continue to be performed throughout the entire duration of these studies.

At this point in the study, the project formulation analysis has just begun and much work remains to be done on two levels. First the project formulation of alternatives must be refined concurrently until a preferred alternative is selected. Then the preferred alternative must be evaluated at a higher level to optimize reservoir storage and conveyance capacities to reduce the cost per acre-foot of water as much as possible. This requires that additional iterative operation studies be run to test each revised project formulation to determine its yield for comparison to the reformulated project cost. This process continues throughout the entire study period until the final feasibility-level report on the preferred project is finalized.